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memorandum

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Subject: RESULTS OF ROOM TEMPARETURE TESTS ON ANL SPOKE CAVITY (340 MHz, beta=0.291)

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Abstract

To benchmark computer codes (MICAV and MAFIA) being used for the design of spoke cavities, we performed RF and structural tests on the cavity loaned from Argonne National Laboratory (we call this cavity ANL cavity). We performed the tests twice and the difference of the data was 15-19 %. Most part of inaccuracy comes from that of load sensor whereas the position sensor was quite accurate. In comparison with these tests, the results of MICAV calculations showed 0.26 % lower resonance frequency, 20 % higher tuning sensitivity, and 29 % higher spring stiffness. These agreements are good considering the difference between the input model and the real cavity, i.e., thickness, welding method and size, as well as the repeatability of the data. In addition, the simulation on the axial electric field distribution showed excellent agreement with the bead-pull measurement.

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1. Introduction

Elliptical superconducting cavity structures have been well adopted in large accelerators such as LEP at CERN, CEBAF at TJNAF and TRISTAN/KEKB at KEK since late 80s. In the past few years, application of such cavities to low-β sections of proton linacs has been discussed in various laboratories. The consensus being made is that elliptical cavities of β lower than ~0.45 appear to be unrealistic in terms of the cavity shape/size and mechanical stability. Different types of superconducting structure for accelerating lower β protons and ions have been developed at Argonne National Laboratory (ANL) since late 80s [1]. Figure 1 shows a coaxial half-wave resonator (left) and spoke cavity (right). Due to its better manufacturability and expandability toward multi-gap structure, spoke cavity has become the choice of further development. A 2-gap 855-MHz β=0.3 spoke cavity was built and successfully tested at ANL (7.2 MeV/m in CW) in 1992 [2]. Then, they decided to build 350 MHz cavities to allow larger beam aperture, lower BCS resistance and higher voltage gain [3]. They built two cavities of β=0.3 and 0.4. One of these two cavities was loaned to LANL in November 2000. Figure 2 shows a photograph of the cavity. The objectives of testing this cavity at LANL were (1) familiarize ourselves with this type of cavity since we had had no experience on this cavity before, (2) benchmark the simulation codes (MICAV and MAFIA) being used for RF and structural analyses and (3) predict achievable Q_0 and accelerating gradients with our present technology. In this memorandum, we describe the methods and results of the tests conducted at room temperature to benchmark the simulation codes. The results at low temperatures (4 K and 2 K) will be reported elsewhere.

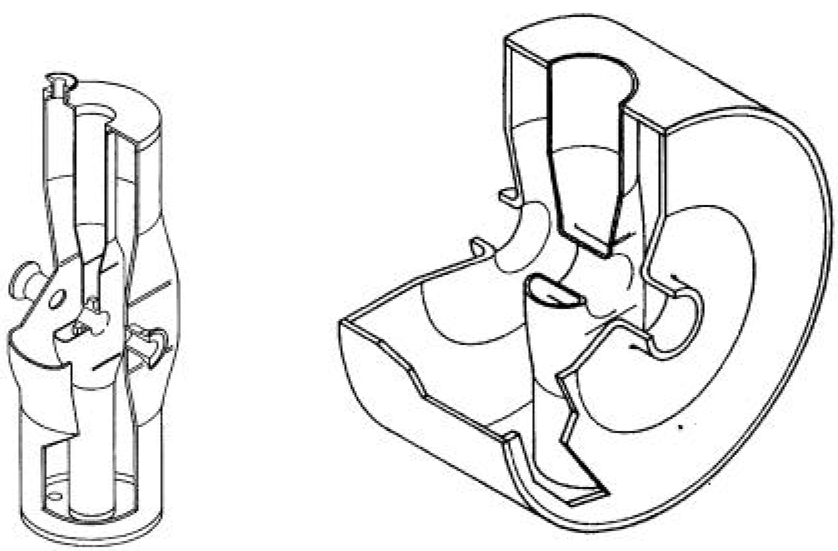

Fig. 1: Coaxial half-wave resonator (left) and spoke resonator (right) [1].

Fig. 2: A photograph of the ANL cavity on loan from ANL.

2. Measurement Set-up

We used a tuning bench that has been used for tuning APT cavities. Figure 3 shows a schematic of the equipment with the spoke cavity mounted. Axial ports of the ANL cavity were attached to aluminum plates using Voss clamps. One of the triangular arms is fixed and the other moves by cranking the handle at the end of the equipment as shown in Fig. 3. The cavity is pushed or pulled horizontally in the direction shown as an arrow in Fig. 3. Figure 4 shows a photograph of the cavity mounted on the tuning bench with position sensors on both sides. The cavity sits on a V-shaped stand whose top is lined with Teflon

Table 1 shows the devices used for the measurements.

Table 1: Devices used for the measurements.

Equipment	Manufacturer	Product name	Measurement range	Resolution
Position sensor and remote unit	Starret	Wisdom	0-1 inch	0.00005 inch
Load sensor	Strainsert	Digital Load Indicator	0-16,000 lb	1 lb
Network analyzer	HP	8720 Network Analyzer	130 MHz - 20 GHz	N/A

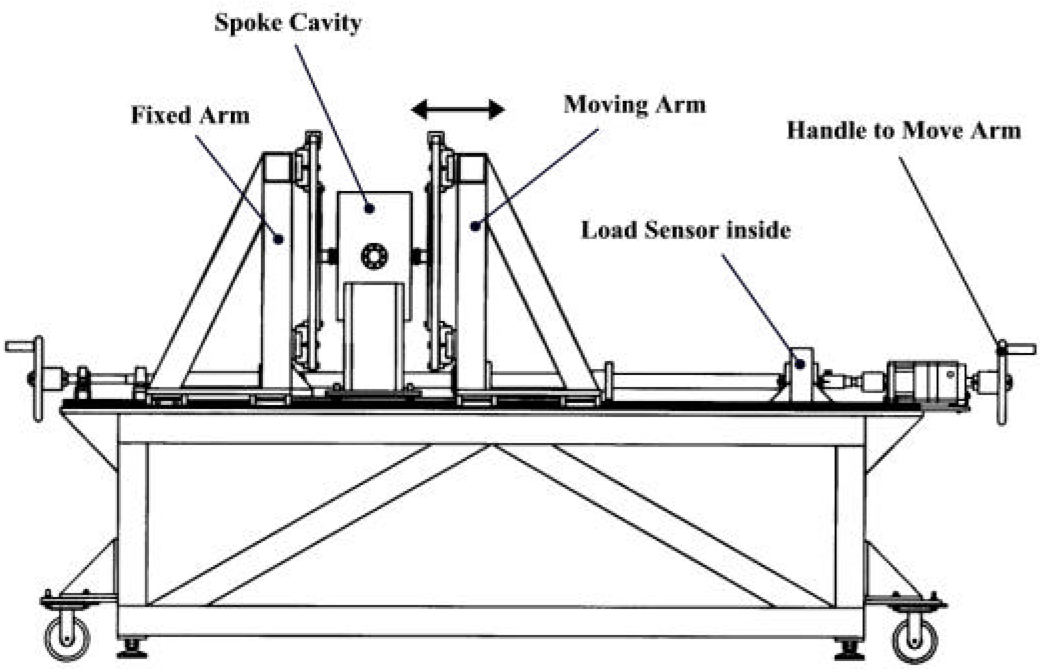

Fig. 3: Schematic (side view) of the set-up of the equipment used for tuning sensitivity measurements.

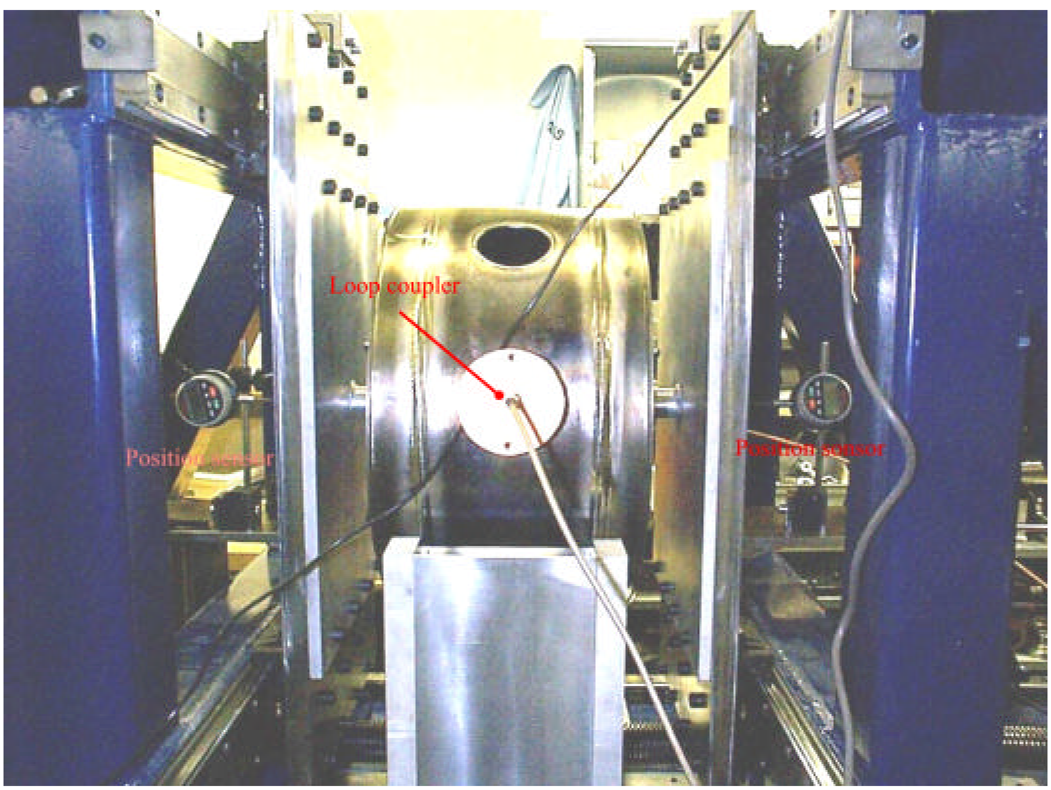

Fig. 4: A photograph (side view) of the ANL spoke cavity being mounted on the tuning bench.

3. Measurement procedure

Though fixed, the left arm slightly moved with the force exerted through the cavity. Thus we measured the displacements of the axial ports on both sides of the cavity using a linear position sensor independently attached to the base of the tuning bench. The net displacement of the cavity was calculated as the difference of the two position sensors.

4. Results

4.1. Displacement versus load

Figure 5 shows the cavity displacements as a function of the force. The solid line is a linear fitting of the data whose equation is written in the figure. The deviation from the straight line comes mainly from the inaccuracy of the load measurements.

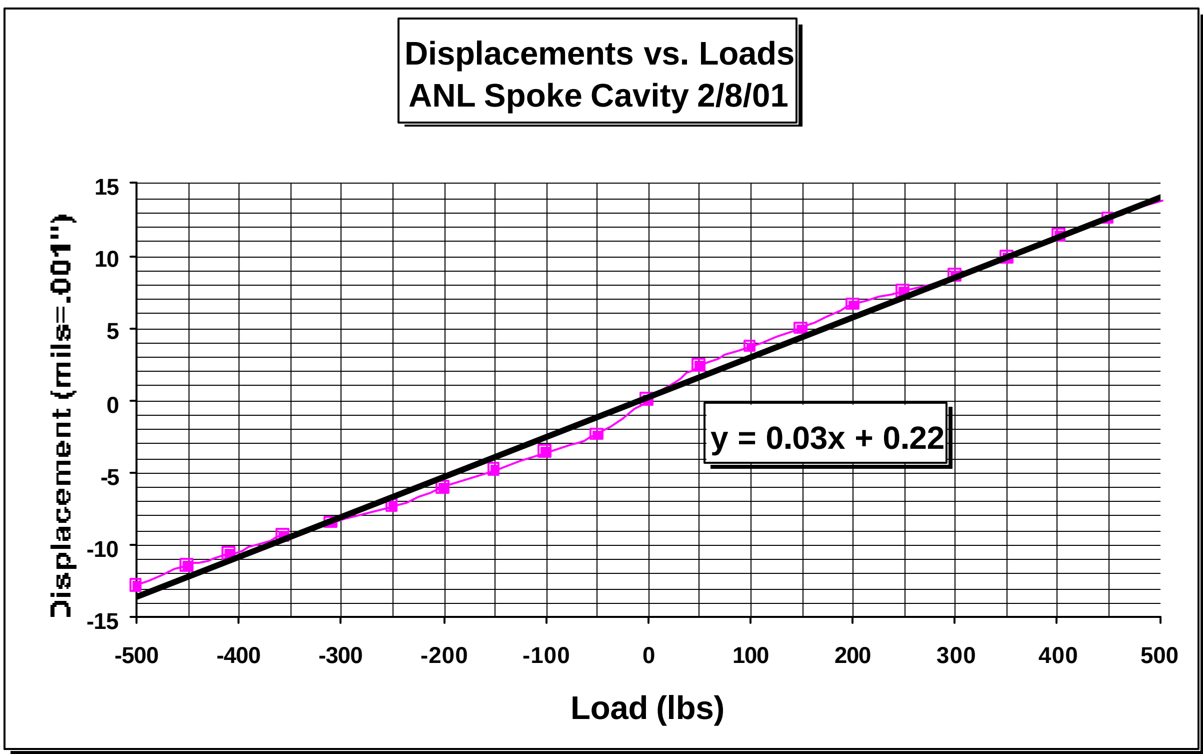

Fig. 5: Displacement as a function of load. Negative load means compression.

4.2. Frequency shift versus displacement

Frequency was measured using a loop coupler attached on one of the radial ports as shown in Fig. 4. Figures 6 and 7 show frequency shifts as a function of axial displacements of the cavity, of which data were taken on different date as shown in each figure.

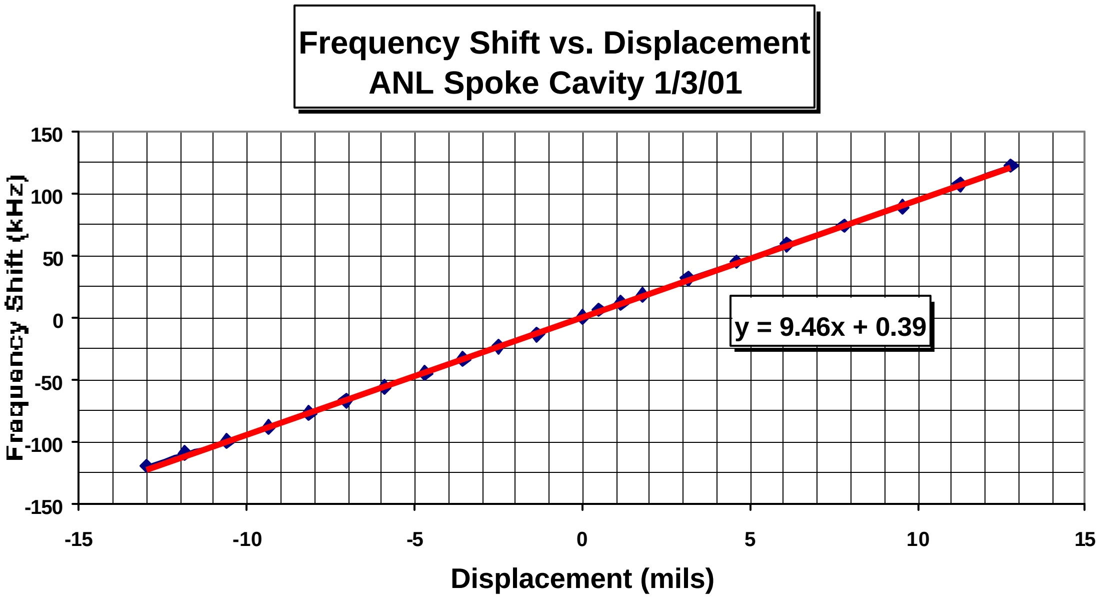

Fig. 6: Frequency shift as a function of displacement in the first test. Negative displacement means compression.

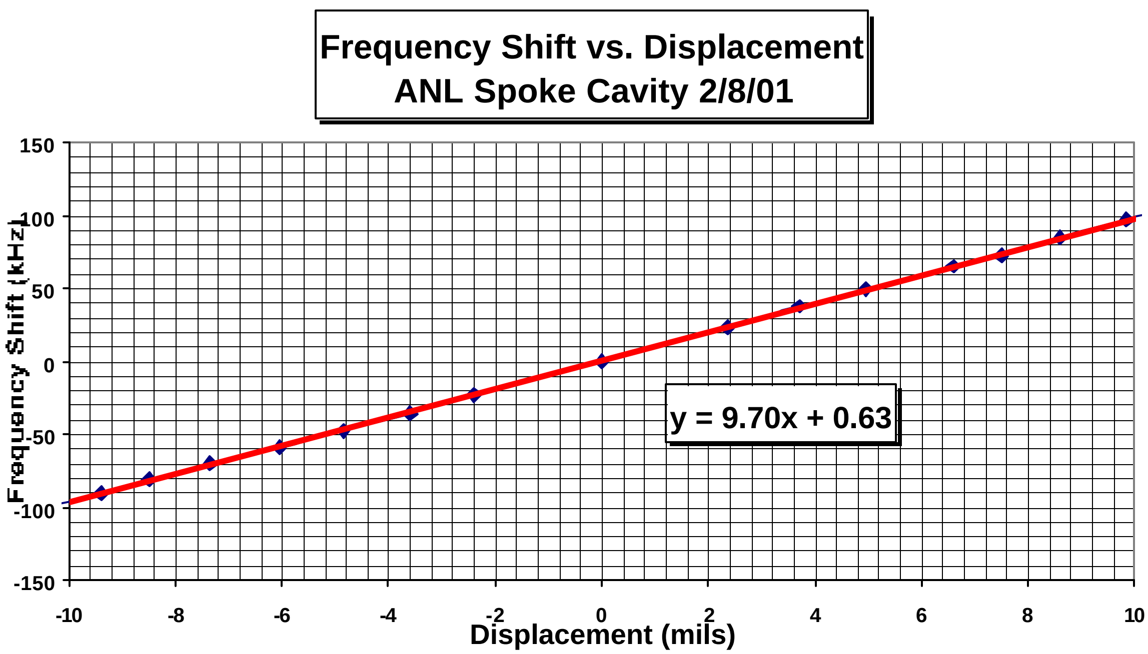

Fig. 7: Frequency shift as a function of displacement in the second test. Negative displacement means compression.

As you can notice, data points show excellent linearity, which indicates that the position measurements were very accurate, needless to say about the frequency measurements.

4.3. Frequency shift versus load

Figure 8 shows frequency shifts as a function of axial load. The solid line is a fitting curve. The deviation from the straight line stems from the error of the load measurements as stated before.

Table 2 summarizes the results and compares them with the results obtained from simulations with MICAV and COSMOS/M [4].

Table 2: Summary of measurements and comparison with simulation results.

	Measured	Simulation (MICAV, COSMOS/M)	Error (%)
Accelerating mode frequency (MHz)	339.699401	338.821495	-0.26
Tuning sensitivity (MHz/in)	9.356	11.32	+21.03
Structural stiffness (lb/mil)	34.36	44.4	+29.22
Tuning sensitivity for load (kHz/lb)	0.272	0.255	-6.35

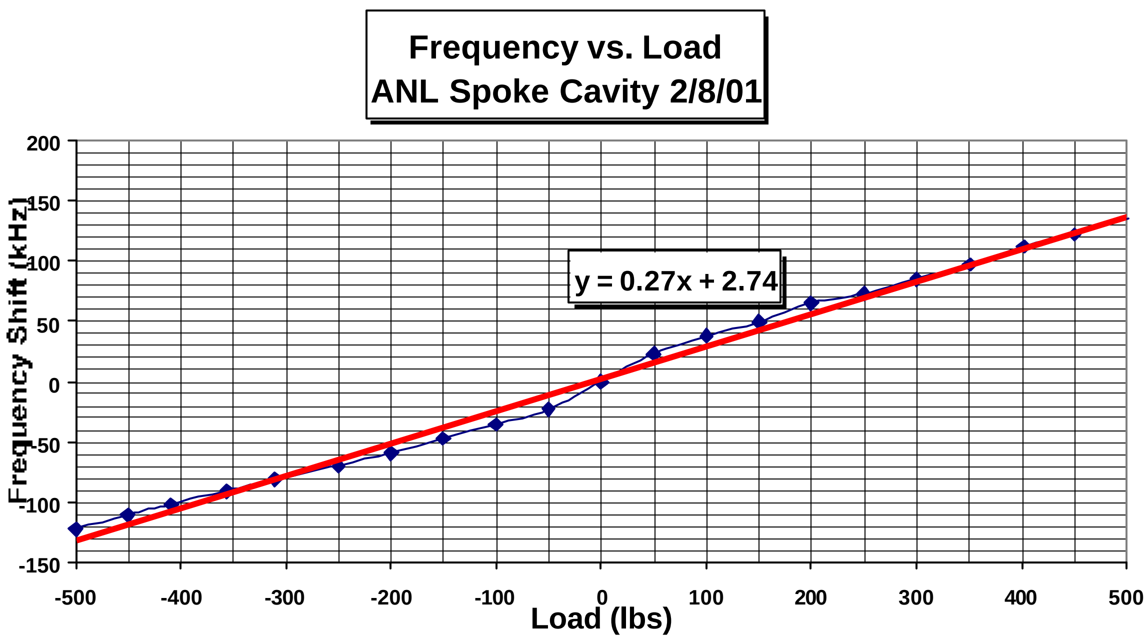

Fig.8: Frequency shift as a function of load. Negative load means compression.

2.4 Axial field profile

Conventional bead-pull method was used to obtain axial electric field profile. The frequency change caused by the presence of the bead along the beam axis was measured. Figure 9 shows the frequency change as a function of the location of the bead along the beam axis. The two dips indicate the location of the gaps. The lower frequency means higher electric field. More accurately speaking, the frequency shift is proportional to the square of the electric field at the bead location. In the figure, the simulation results of MICAV and MAFIA [5] are also shown. As one can see in Fig. 9, simulation results and measurement data are in excellent agreement.

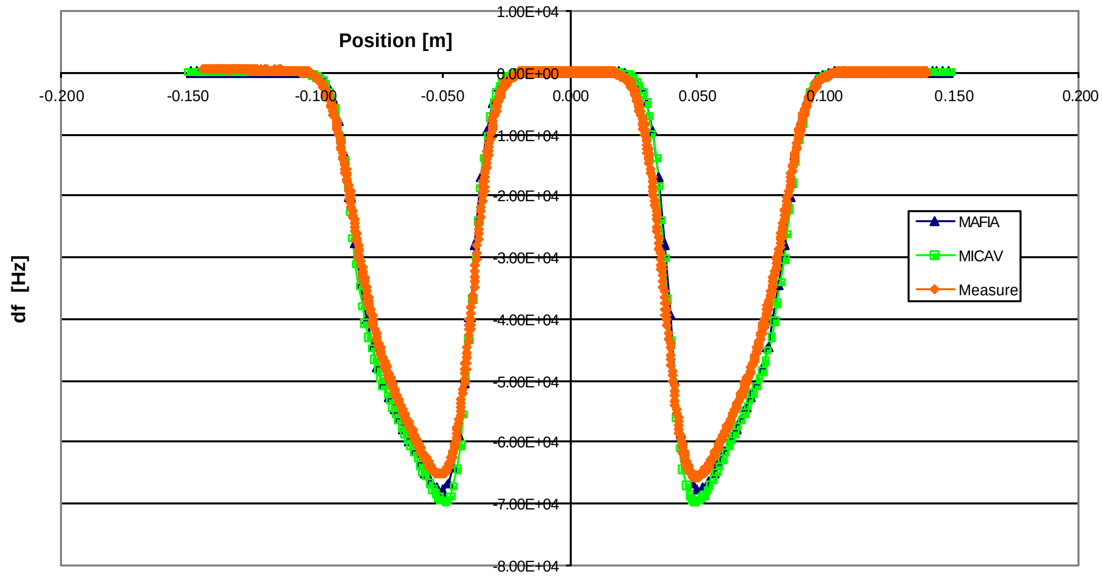

Fig. 9: Bead pull measurement results on beam axis compared with simulations. Frequency shift df is proportional to the square of axial electric field. The center of horizontal axis corresponds to the cavity center.

5. Summary

Benchmarking of simulation codes MICAV(COSMOS/M) and MAFIA was performed using a spoke cavity loaned from ANL. Simulation results agreed with the measurements within 30 %, which seems good enough at this stage of designing. Errors seem to come from inaccuracy of load measurement and the difference of the real cavity and the input model.

6. References

[1] J. R. Delayen et al., *Recent developments in the application of t RF superconductivity to high-brightness and high-gradient ion beam accelerators*, Proc. 5th Workshop on RF Superconductivity, pp. 376-394, DESY, August 1991.

[2] J. R. Delayen et al., *Design and test of a superconducting structure for high-velocity ions*, 1992 Linear Accelerator Conference, Ottawa, Ontario, Canada, 24-28 August 1992.

[3] K. W. Shepard et al., *Prototype 350 MHz niobium spoke-loaded cavities*, 1999 Particle Accelerator Conference, New York, March 29 – April 2, 1999.

[4] These simulations were performed by Richard LaFave.

[5] Simulation with MAFIA was conducted by Frank Krawczyk.